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by

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ABSTRACT

Pressure distribution networks are gaining popularity for use in subsurface soil absorption systems to overcome problem sites. Several design procedures are used and their applications vary. Few studies have been made to evaluate the different designs and their effectiveness. This paper reviews the published data and makes recommendations for further study.

INTRODUCTION

The objectives of good subsurface soil absorption field design are to maintain adequate treatment and reasonable soil infiltration rates over a long system life. The manner in which wastewater is distributed within the absorption field may be critical to meeting these objectives. Localized overloading of the infiltrative surface from poor distribution may result in inadequate treatment of the wastewater in rapidly permeable soils and accelerated clogging in all soils (Bouma, 1975; Robeck *et al.*, 1964; McGauhey and Winneberger, 1964). The 4 in diameter perforated pipe traditionally used to distribute septic tank effluent within soil absorption systems has been shown to provide very uneven distribution (Converse, 1974; Univ. of Wisconsin, 1978). Concern about the effects of localized overloading on absorption field performance has resulted in increased use of pressure distribution networks because they provide more uniform distribution than other network designs.

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Pressure distribution networks differ from conventional distribution networks in that the wastewater is periodically dosed into the piping at such a rate that the network is completely filled and pressurized by the liquid rather than operating under gravity flow conditions. The objective is to supply equal amounts of liquid to all perforations in the network simultaneously. This is accomplished by proper sizing of the pipe diameters in relation to the selected perforation diameter and spacing. For individual home systems, the laterals are commonly 1 in to 2 in in diameter with 1/8 in to 1/4 in diameter holes drilled 24 in to 30 in apart along the inverts. Pumps or siphons are used to pressurize the network.

Pressure distribution networks were first developed at the University of Wisconsin to improve the performance of mound systems (Bouma *et al.*, 1975). Conventional 4 in diameter perforated piping was found to distribute the septic tank effluent unevenly along the length of the gravel trench within the mound such that short circuiting of the effluent out of the mound resulted. Replacement of the conventional piping with smaller perforated piping designed to discharge equal amounts of liquid out each hole under pressure corrected this problem (Converse, 1974; Converse *et al.*, 1975).

Since their introduction for use in mound systems, pressure distribution networks have found wider application. Many states now use them in trench or bed systems to overcome various problem sites because it is felt that the more uniform distribution these networks provide will reduce the risk of groundwater contamination or increase the life of the system. Yet it remains to be shown that more uniform distribution significantly improves absorption field performance. It is the objective of this paper to review what is known about the performance of absorption systems utilizing pressure distribution networks and make recommendations for further study.

NETWORK DESIGNS AND APPLICATIONS

Several different pressure distribution network designs are currently in use and the conditions under which they are applied also differ. The primary types of networks identified are the Wisconsin Pressure

Distribution Network, (WPDN), Low Pressure Pipe System (LPP), and Pressurized Subsurface Effluent Dosing (PSED). Other network designs are variations of these basic types. The applications of each type are given in Table 1.

Table 1.

Applications of Pressure Distribution Networks

Wisconsin Pressure Distribution Networks

Rapidly and very rapidly permeable soils

Shallow soil depths

Restricted area

Large flows

Low Pressure Pipe

Rapidly permeable soils

Shallow water tables

Shallow restrictive horizons

Large flows

Rehabilitation

Pressurized Subsurface Effluent Dosing

Slowly permeable soils

Evapotranspiration

Wisconsin Pressure Distribution Network

Several states have adopted the Wisconsin Pressure Distribution Network or variations of it for use in conventional trench and bed systems installed in very rapidly or rapidly permeable soils and soils with shallow depths to limiting conditions, mound systems, and large cluster systems. In Oregon (1982) pressure distribution is required where the minimum separation between the bottom of the system and underlying soils having permeabilities defined as very rapid or rapid is less than 18 in. Minnesota (undated) prohibits conventional system installation in soils with percolation rates faster than 5 min/in except where pressure distribution is used. Washington (1981) and Wisconsin (1980) require pressure distribution where the system must be raised in the soil profile to maintain 36 in vertical separation between the bottom of the system and a limiting condition. Wisconsin is alone in allowing reductions in bottom infiltration area of trenches and beds if pressure

distribution is used (See Table 2).

Table 2
Comparative Effluent Application Rates in Wisconsin (State of Wisconsin, 1980)

Perc Rate (min/in)	<u>Conventional Distribution</u>		<u>Pressure Distribution</u>	Percent Difference*
	Trenches (gpd/ft ²)	Beds (gpd/ft ²)	Trenches & Beds (gpd/ft ²)	
0 to <10	0.91	0.73	1.20	32
10 to <30	0.60	0.48	0.80	33
30 to <45	0.50	0.40	0.72	44
45 to 60	0.45	0.36	0.40	- 11

* Percent difference from conventional trench systems

Low Pressure Pipe System

Unlike the Wisconsin network, the Low Pressure Pipe System is not used in conventional trenches or beds. The LPP system is a series of shallow narrow trenches incorporating pressure distribution. It was developed at North Carolina State University as an alternative to conventional soil absorption systems in "provisionally suitable" and "unsuitable" soils as defined by the State of North Carolina (Carlile, 1980, State of North Carolina, 1981). These soils include the rapidly permeable coastal sands, inland coastal soils with shallow water tables, soils with shallow restrictive horizons, and steeply sloping soils. Depths to limiting conditions from the natural graded surface may be reduced to as much as 18 in. with LPP systems but the minimum vertical separation between the trench bottom and the limitation must be 12 in. as required for conventional trench and bed systems.

Sizing of the LPP absorption area differs from conventional design. Rather than sizing the liquid/soil interface (infiltrative surface), the entire area that the system occupies is sized using loading rates presented in Table 3. Within this area, trenches 4 in to 6 in wide are spaced a minimum of 5 ft apart (Triangle J Council of Governments, 1979). The idea behind this sizing criterion is to prevent exceeding

the site's capacity to accept the liquid.

Table 3

Comparison of Sizing Requirements for Conventional and LPP Systems in North Carolina (Triangle J. Council of Governments, 1979)

Conventional				Low Pressure Pipe System			
Percolation Rate	Soil Texture	Bottom Area Loading Rate	Estimated Infiltrative Surface Loading Rate ¹	Percolation Rate	Soil Texture	Areal Loading Rate ²	Estimated Infiltrative Surface Loading Rate ³
min/in		gpd/ft ²	gpd/ft ²	min/in		gpd/ft ²	gpd/ft ²
0.30	Sandy, loamy	0.75	0.90	Faster than 20	Sand, loamy sand	0.50-0.40	1.0-0.8
				20-40	Sandy loam, silt loam	0.40-0.30	0.8-0.6
31-60	Clayey	0.75	0.45	40-60	Sandy clay loam, clay loam	0.30-0.20	0.6-0.4
				60-90	Silty clay loam, sandy clay	0.20-0.10	0.4-0.2
61-120	Clayey	0.50	0.30	90-120	Silty clay, clay	0.10-0.05	0.2-0.1

¹ Exposed sidewall and bottom area assuming 3 ft wide trenches with 12 in of gravel.

² Total area within system perimeter.

³ Exposed sidewall and bottom area assuming 6 in wide trenches with 12 in of gravel spaced 5 ft on center.

Pressurized Subsurface Effluent Dosing

As in the LPP system, the piping network of Pressure Subsurface Effluent Dosing systems cannot be separated from the rest of the system design. In PSED systems, the piping is installed in shallow narrow trenches without gravel. The soil's percolation rate determines the length of distribution piping as shown in Table 4 (Hart, 1980). The system operates as a trickle irrigation system performing best in dry climates. In Texas, reduced infiltration areas are not permitted if PSED systems are used but because the pipe is trenched in without gravel, system construction is much less costly. Utilizing evapotranspiration also permits systems to be installed where the percolation rate is slower than 60 min/in.

Table 4
Comparison of PSED and Conventional System Loading
Rates in Texas (Hart, 1980; State of Texas, undated)

Percolation Rate	Conventional System Loading Rates	PSED Pipe Length	Estimated Loading Rate ¹
min/in	gpd/ft ²	ft/gpd	gpd/ft ²
1-5	1.2	-	-
6-15	0.8	1.0	1.0
16-30	0.6	1.5	0.7
31-45	0.5	2.3	0.4
46-60	0.4	3.0	0.3
61-140	-	3.0-10.0	0.3-0.1

¹ 1 ft of pipe is assumed to be equivalent to 1 ft² of conventional trench bottom area.

NETWORK PERFORMANCE

To evaluate the effectiveness of pressure distribution networks three basic questions must be answered:

1. Is the distribution provided by current pressure network designs uniform?
2. Does uniform distribution significantly improve the treatment efficiency of rapidly and very rapidly permeable soils over conventional distribution methods and is that level of treatment adequate?
3. Does uniform distribution significantly reduce the rate or degree of soil clogging from that which occurs at the infiltrative surface of systems using conventional distribution methods?

Uniformity of Distribution

There are two frames of reference from which the uniformity of distribution may be judged 1) the soils infiltrative surface, and 2) the outlets of

the distribution laterals. The objective is to achieve the former by controlling the latter. It is the latter which is of interest in addressing the first question for if the design model produces uniform discharge rates out each hole in the distribution network then the density of holes within the network may be changed to achieve the desired uniformity of distribution over the soils infiltrative surface.

Several different methods are currently in use to design the networks. The most commonly used was developed from the Hazen-Williams and orifice equations (EPA, 1980; Otis, 1982). By selecting the size and spacing of the lateral perforations the procedure sizes the lateral and manifold diameters such that the rate of discharge from any two perforations vary no more than 10 percent along the length of the lateral and no more than 15 percent throughout the network.

To determine the accuracy of the design model, Converse and Otis (1982) monitored the in-line lateral and manifold pressures of 10 operating networks with design capacities of 450 gpd to 15,000 gpd. The recorded pressures were used to calculate the actual network losses for comparison with the losses predicted by the design model. Results of this limited field study showed great variability in performance. Ratios of measured losses to design losses ranged from 0.11 to 1.98. This wide variability was attributed to differences in construction quality and wastewater characteristics. However, the design model proved to be adequate except when lateral lengths exceeded 80 percent of the maximum length allowed by the model.

Another design model was developed by Mote et al. (1981, 1982) with particular emphasis on sloping site conditions. This model uses the Darcy-Weisbach equation and Christiansens factor to estimate pressures at the inlet to each lateral. The discharge rates out each perforation in the lateral are assumed to be equal. Selection of the lateral diameter is based on the total calculated flow at its inlet over its entire length. Using friction head loss tables from pipe manufacturers, lateral diameters are selected which show friction losses to be less than 5 percent of the total head on the highest lateral (Mote et al., 1981).

A computerized design procedure was developed in which the designer selects the orifice diameter, maximum orifice spacing and the lateral diameter from which the computer then calculates the number of orifices required in each lateral (Mote et al., 1982). The drawback to this procedure is that to obtain the desired density of holes, the designer must select the proper lateral diameter.

To confirm the accuracy of the design procedure a network consisting of 4 3/4-in diameter laterals each 20 ft long with 1/8-in diameter holes spaced 4 to 5 ft apart was tested under laboratory conditions. The 4 laterals were set at three different elevations. Results of the testing showed that the predicted lateral discharge rates were within 10.3 percent of the measured rates (Mote et al., 1982).

The hydraulic design of the LPP and PSED networks is not so sophisticated because of the nature of the systems' operations. Apparently, in neither system is uniform distribution sought, rather the pressure networks are used only to insure that effluent is delivered to all parts of the system.

Table 5 compares the various design criteria from different states using pressure distribution. Because the criteria vary, the maximum length of a 1 1/4-in lateral with 1/4-in holes spaced 30 in apart was computed for each state. Arkansas is the most conservative. The other states using WPDN compare reasonably well differing primarily in minimum hole size and spacing permitted. The LPP and PSED systems are much less conservatively designed resulting in extremely long lateral lengths.

Treatment Efficiency

Several studies have been conducted that have examined the water quality in the unsaturated or saturated zones below disposal systems with pressure networks. Unfortunately, none of the studies used controls or replicates so the data are not conclusive.

Table 5

Comparison of Pressure Distribution Network Designs

Network Type	Min. Hole Dia. (in)	Max. Hole Spacing (ft)	Max. Lat. Spacing (ft)	Min. Distal Press. (ft H ₂ O)	Friction Coefficient	Max. Variations of Hole Discharge (%)	Max. Lat. Length ¹ (ft)
WPDN							
Arkansas	1/8	5	-	-	2	3	15
Minnesota	3/16	3	5	5	-	15	37.5
Oregon	1/8	2-4 ⁴	4	5	150 ⁵	8.6 ⁶	32.5
Washington	3/16	3	5	-	150 ⁵	15	37.5
Wisconsin	1/4	5-10	5-10	2	150 ⁵	15	37.5
LPP							
North Carolina	1/8	5	5(min)	1	150 ⁵	-	70
PSED							
Texas	1/8	0.25	-	-	-	-	100

¹ 1/4-in lateral with 1/4-in holes spaced 30 in apart.

² Pipe manufacturers friction loss tables used.

³ Hole discharge rates assumed equal.

⁴ 2 ft in coarse textured soils, 4 ft in finer textured soils.

⁵ Hazen-Williams friction coefficient.

⁶ Maximum head variation of 15%.

Converse *et al.* (1975) and the University of Wisconsin (1978) describe the results of laboratory work with sand and silt loam columns which showed the importance of maintaining unsaturated soil conditions for high treatment efficiency. They postulated that pressure distribution networks could best provide the loading regime which would result in unsaturated flow in coarse granular or strongly structured soils. This postulation was substantiated somewhat in the field by comparing 2 mound systems. One of the mounds used conventional distribution piping which resulted in short circuiting of the effluent out the side of the mound where high fecal coliform counts were found. The second mound used a pressure network. No short circuiting occurred and samples of the soil moisture below the mound showed nearly complete removals of fecal indicators. However, the fill materials and waste sources were different.

A second study was conducted in Oregon and described by Ronayne *et al.* (1982). Six trench systems with pressure networks were studied. Three were installed in soils with sand, loamy sand, and sandy loam textures

with depths to groundwater ranging from 29 in to 48 in. The remaining three were installed in soils with silt loam, loam, and clay loam textures. Water tables in these soils ranged from 2 in to 32 in. Groundwater samples were taken up gradient and down gradient of the system but the liquid entering the trenches was not sampled. Only in the second group installed in the finer textured soils was a trench system with conventional distribution available for comparison. The results of this study showed only that an adequate depth of unsaturated soil must exist between the bottom of the trench and the groundwater table if good treatment is to be achieved. In this case, 30 in vertical separation was found to be sufficient. No conclusions could be drawn concerning the method of distribution.

The third study investigated the performance of LPP systems in North Carolina (Carlile *et al.*, 1981). As in Oregon, the study showed the importance of the unsaturated zone below the system for treatment. No conclusions could be drawn regarding the advantages to the method of distribution.

Clogging Mat Resistance

A number of investigators have shown that periodic dosing of effluent onto the soils infiltrative surface with periods of rest between doses retards clogging (Bendixen *et al.*, 1950; Winneberger *et al.*, 1960; Jones and Taylor, 1965; Thomas *et al.*, 1966; University of Wisconsin, 1978). However, none of these investigators recommend that the application rates be increased if dosing is provided. It is only in an isolated study by Bouma *et al.* (1974) that indicates that pressure distribution might permit higher loadings. In the study, a trench constructed in a well structured silt loam soil was dosed once daily at a rate of 0.8 gpd/ft^2 of trench bottom area. Conventional design loadings which represent peak loadings for this soil are 0.6 gpd/ft^2 . After 9 years, this system continues to operate. Its success is attributed to worm activity within the clogging mat permitted by the intermittent loading. In another study of several mound systems in Wisconsin, Harkin *et al.* (1979) reported that clogging mats were not developing due to the pressure distribution. However, none were loaded near capacity. Since their observations, clogging mats have developed in some of the mounds.

In a carefully controlled study with field lysimeters installed in a silt loam soil Hargett et al. (1982) showed that dosing did retard clogging but that it did not permit increased loading rates. The lysimeters which simulated gravity flow (8 small doses daily) ponded within 16 months while the dosed lysimeters (1 dose daily) did not pond at all over the 20 month study. Both sets of lysimeters received 2 cm/day of effluent. The lysimeters were small enough so that the dosed lysimeters could be considered to have had uniform distribution.

DISCUSSION

The review of published data indicates that the claim that pressure distribution networks are superior to conventional distribution networks is based more on conjecture than fact. Except for their application in mound systems where they have been demonstrated to be necessary to prevent short circuiting of wastewater through the fill, pressure distribution networks have not been shown to improve the soils efficiency to treat the waste nor to retard soil clogging over conventional gravity or dosed flow networks.

Work by the University of Wisconsin showed the correlation between the soil moisture regime and adequate treatment but the ability of pressure distribution networks to maintain that proper moisture regime has not been demonstrated. The design models used today work reasonably well in sizing a network which distributes liquid uniformly between each perforation, but the density of perforations within the absorption system necessary to prevent soil moistures which are too high have not been determined. More work is necessary in this area to establish how uniform the distribution need be to obtain the desired results.

Retardation of soil clogging through the use of pressure networks also has not been adequately demonstrated. Dosing has been shown to be beneficial by several investigators but not to the extent that increased loading rates can be used. In large systems, pressure distribution is probably beneficial in distributing the liquid to all parts of the absorption system to achieve the maximum benefit from dosing, but in small systems, it is doubtful uniform distribution is superior to conventional dosing.

Clearly, further work is needed to determine the effectiveness of pressure distribution networks. The use of the networks in mounds to prevent short circuiting and in large cluster systems to maximize the benefits of dosing seems warranted. However, their exclusive use in coarse textured soils does not seem justified. Conventional systems have not been shown to result in a greater risk for groundwater contamination although intuitively it would seem so. Demonstrations in coarse textured soils comparing the impacts of conventional and pressure networks in the groundwater are needed.

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